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METHOD FOR PROTECTING NORMAL CELLS FROM CYTOTOXICITY OF CHEMOTHERAPEUTIC AGENTS

Cross-Reference to Related Application

5 The benefit of the filing date of U.S. provisional patent
 application Ser. No. 60/159,123, filed October 12, 1999, is hereby claimed
 pursuant to 35 U.S.C. 119(e), and the entire disclosure thereof is
 incorporated herein by reference.

Field of the Invention

10 The invention relates to the field of anticancer chemotherapy,
 and cytoprotective agents administered before, during or after anticancer
 chemotherapy to protect the normal cells of the patient from the cytotoxic
 effects of anticancer chemotherapeutics.

Background of the Invention

15 Experimental chemotherapy has been the mainstay of
 treatment offered to patients diagnosed with surgically unresectable
 advanced cancers, or cancers refractory to standard chemotherapy and
 radiation therapy. Of the more effective classes of drugs, curative
 properties are still limited. This is because of their relatively narrow
 therapeutic index, restricted dosage, delayed treatments and a relatively
 20 large proportion of only partial tumor reductions. This state is usually
 followed by recurrence, increased tumor burden, and drug resistant tumors.

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Several cytoprotective agents have been proposed to enhance the therapeutic index of anticancer drugs. For methotrexate toxicity, such agents include asparaginase, leucovorin factor, thymidine, and carboplatin. Because of the extensive use of anthracyclines, specific and non-specific cytoprotective agents have been proposed which have varying degrees of efficacy; included are corticosteroids, desazoxane and staurosporin. The latter is of interest in that it includes a G1/S restriction blockade in normal cells. (Chen *et al.*, *Proc AACR* 39:4436A, 1998).

Cisplatin is widely used and has a small therapeutic index which has spurred investigation and search of cytoprotectants. Among the cytoprotectants for cisplatin with clinical potential are mesna, glutathione, Na-thiosulfate, and amifostine (Griggs, *Leuk. Res.* 22 Suppl 1:S27-33, 1998; List *et al.*, *Semin. Oncol.* 23(4 Suppl 8):58-63, 1996; Taylor *et al.*, *Eur. J. Cancer* 33(10):1693-8, 1997). None of these or other proposed cytoprotectants such as oxonic acid for fluoropyrimidine toxicity, or prosaptide for paclitaxel PC12 cell toxicity, appears to function by a mechanism which renders normal replicating cells into a quiescent state.

What is needed are cytoprotective agents which are effective in protecting animals, inclusive of humans, from the cytotoxic side effects of chemotherapeutic agents.

Unrelated to the foregoing, styryl sulfones having pharmaceutical utility as anticancer agents have been reported in WO/99/18068, the entire disclosure of which is incorporated herein by reference. The compounds inhibit tumor cell growth by inducing tumor cell death without killing normal cells. The styryl sulfones are effective in a broad range of tumor types. Without wishing to be bound by any theory, it is believed that the styryl sulfones affect the Mitogen Activated Protein Kinase (MAPK) signal transduction pathway, thereby affecting tumor cell growth and viability.

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Summary of the Invention

It is an object of the invention to provide compositions and methods for protecting animals, inclusive of humans, from the cytotoxic side effects of chemotherapeutic agents, particularly mitotic phase cell cycle inhibitors and topoisomerase inhibitors, used in the treatment of cancer and other proliferative disorders.

It is an object of the invention provide a method for treating cancer or other proliferative disorder which reduces or eliminates cytotoxic effects on normal cells.

It is an object of the invention to enhance the effects of chemotherapeutic agents, particularly mitotic phase cell cycle inhibitors and topoisomerase inhibitors, used for the treatment of cancer or other proliferative disorders.

It is an object of the present invention to provide a therapeutic program for treating cancer or other proliferative disorder which includes administration of a cytoprotective compound prior to administration of a chemotherapeutic agent, which cytoprotective compound induces a reversible cycling quiescent state in non-tumored tissues.

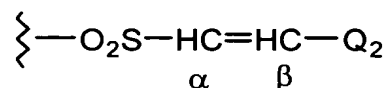
It is an object of the invention to provide a method for safely increasing the dosage of chemotherapeutic agents, particularly mitotic phase cell cycle inhibitors and topoisomerase inhibitors, used in the treatment of cancer and other proliferative disorders.

According to the present invention, a method for protecting an animal from cytotoxic side effects of the administration of a mitotic phase cell cycle inhibitor or a topoisomerase inhibitor comprises administering to the animal, in advance of administration of the aforesaid inhibitor, an effective amount of at least one cytoprotective α,β unsaturated aryl sulfone compound. The term "animal" is meant to embrace human beings, as well as non-human animals.

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By "α,β unsaturated aryl sulfone compound" as used herein is meant a chemical compound containing one or more α,β unsaturated aryl sulfone groups:

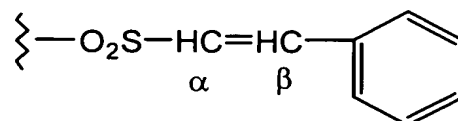


wherein Q₂ is substituted or unsubstituted aryl, and the hydrogen atoms attached to the α and β carbons are optionally replaced by other chemical groups.

By "substituted" means that an atom or group of atoms has replaced hydrogen as the substituent attached to a ring atom. The degree of substitution in a ring system may be mono-, di-, tri- or higher substitution.

The term "aryl", alone or in combination, means a carbocyclic aromatic system containing one, two, or more rings wherein such rings may be attached together in a pendent manner or may be fused. The term "aryl" is intended to include not only aromatic systems containing only carbon ring atoms but also systems containing one or more non-carbon atoms as ring atoms. Such systems may be known as "heteroaryl" systems. The term "aryl" is thus deemed to include "heteroaryl". Heteroaryl groups include, for example, pyridyl, thienyl, furyl, thiazolyl, pyrrolyl, and thienyl-1,1-dioxide. The heterocyclic radical may be substituted or unsubstituted. The term "aryl" is not limited to ring systems with six members.

According to one embodiment, the α,β unsaturated aryl sulfone group is a styryl sulfone group:



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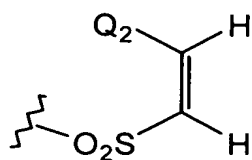
wherein the hydrogen atoms attached to the α and β carbons are optionally replaced by other chemical groups, and the phenyl ring is optionally substituted.

By "styryl sulfone" or "styryl sulfone compound" or "styryl sulfone therapeutic" as used herein is meant a chemical compound containing one or more such styryl sulfone groups.

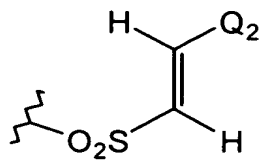
According to another embodiment of the invention, a method of treating an individual for cancer or other proliferative disorder is provided. The method comprises administering to the animal an effective amount of at least one mitotic phase cell cycle inhibitor or topoisomerase inhibitor, and administering before the inhibitor, an effective amount of at least one cytoprotective α,β unsaturated aryl sulfone compound.

By "effective amount" of the mitotic phase cell cycle inhibitor or topoisomerase inhibitor is meant an amount of said inhibitor effective in killing or reducing the proliferation of cancer cells in a host animal. By "effective amount" of the cytoprotective α,β unsaturated aryl sulfone compound is meant an amount of compound effective to reduce the toxicity of the mitotic phase cell cycle inhibitor or topoisomerase inhibitor on normal cells of the animal.

The α,β unsaturated aryl sulfone cytoprotective compounds are characterized by cis-trans isomerism resulting from the presence of a double bond. Stearic relations around a double bond are designated as "Z" or "E". Both configurations are included in the scope of " α,β unsaturated aryl sulfone":



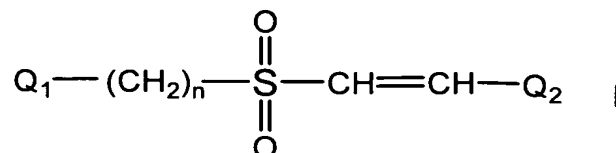
Z configuration



E configuration

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According to one embodiment, the α,β unsaturated aryl sulfone compound is a compound of the formula I:



wherein:

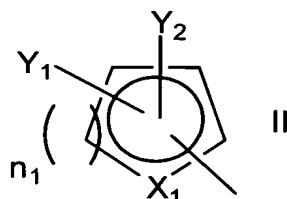
n is one or zero;

5 Q_1 and Q_2 are, same or different, are substituted or unsubstituted aryl.

Preferably, n in formula I is one, that is, the compounds comprise α,β unsaturated benzylsulfones, e.g. styryl benzylsulfones.

According to one sub-embodiment, n is preferably one and:

10 Q_1 is selected from the group consisting of substituted and unsubstituted phenyl, 1-naphthyl, 2-naphthyl, 9-anthryl and an aromatic radical of formula II:

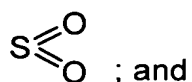


wherein

n_1 is 1 or 2,

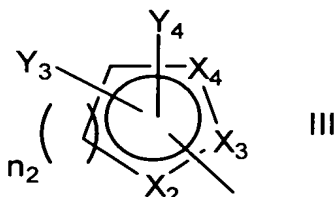
15 Y_1 and Y_2 are independently selected from the group consisting of hydrogen, halogen, and nitro, and

X_1 is selected from the group consisting of oxygen, nitrogen, sulfur and



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Q_2 is selected from the group consisting of substituted and unsubstituted phenyl, 1-naphthyl, 2-naphthyl, 9-anthryl and an aromatic radical of formula III:



wherein

n_2 is 1 or 2,

Y_3 and Y_4 are independently selected from the group consisting of hydrogen, halogen, and nitro, and

X_2 , X_3 and X_4 are independently selected from the group consisting of carbon, oxygen, nitrogen, sulfur and

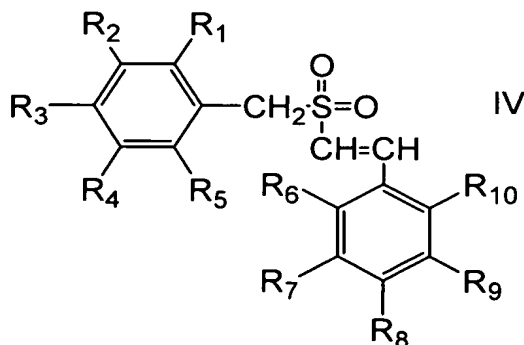


provided that not all of X_2 , X_3 and X_4 may be carbon.

According to one preferred embodiment according to formula 1, Q_1 and Q_2 are selected from substituted and unsubstituted phenyl.

Preferred compounds where Q_1 and Q_2 are selected from substituted and unsubstituted phenyl comprise compounds of the formula

IV:



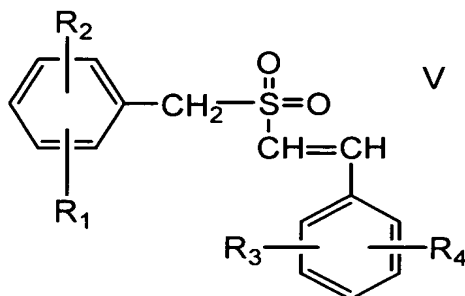
wherein:

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R_1 through R_{10} are independently selected from the group consisting of hydrogen, halogen, C1-C8 alkyl, C1-C8 alkoxy, nitro, cyano, carboxy, hydroxy, phosphonato, amino, sulfamyl, acetoxy, dimethylamino(C2-C6 alkoxy), C1-C6 trifluoroalkoxy and trifluoromethyl.

5 In one embodiment, compounds of formula IV are at least di-substituted on at least one ring, that is, at least two of R_1 through R_5 and/or at least two of R_5 through R_{10} , are other than hydrogen. In another embodiment, compounds of formula IV are at least trisubstituted on at least one ring, that is, at least three of R_1 through R_5 and/or at least three of R_5 through R_{10} , are other than hydrogen.

10 In one embodiment, the cytoprotective compound has the formula V:



wherein R_1 , R_2 , R_3 and R_4 are independently selected from the group consisting of hydrogen, halogen, C1-C8 alkyl, C1-C8 alkoxy, nitro, cyano, carboxy, hydroxy and trifluoromethyl.

15 According to a particularly preferred embodiment of the invention, the cytoprotective compound is according to formula V, and R_1 and R_2 are independently selected from the group consisting of hydrogen, chlorine, fluorine, bromine, cyano, and trifluoromethyl; and R_3 and R_4 are independently selected from the group consisting of hydrogen, chlorine, fluorine and bromine.

20 Preferred compounds according to formula V having the E-configuration include, but are not limited to, (E)-4-fluorostyryl-4-chlorobenzylsulfone; (E)-4-chlorostyryl-4-chlorobenzylsulfone; (E)-2-chloro-

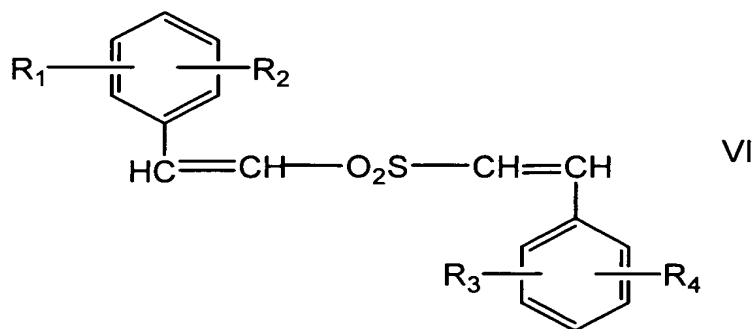
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4-fluorostyryl-4-chlorobenzylsulfone; (E)-4-carboxystyryl-4-chlorobenzyl
 sulfone; (E)-4-fluorostyryl-2,4-dichlorobenzylsulfone; (E)-4-fluorostyryl-4-
 bromobenzylsulfone; (E)-4-chlorostyryl-4-bromobenzylsulfone; (E)-4-
 bromostyryl-4-chlorobenzylsulfone; (E)-4-fluorostyryl-4-
 5 trifluoromethylbenzylsulfone; (E)-4-fluorostyryl-3,4-dichlorobenzylsulfone;
 (E)-4-fluorostyryl-4-cyanobenzylsulfone; (E)-2,4-dichloro-4-
 chlorobenzylsulfone; and (E)-4-chlorostyryl-2,4-dichlorobenzylsulfone.

According to another embodiment, compounds of formula I
 have the Z configuration wherein R_1 and R_3 are hydrogen, and R_2 and R_4
 10 are selected from the group consisting of 4-Cl, 4-F and 4-Br. Such
 compounds include, for example, (Z)-4-chlorostyryl-4-chlorobenzylsulfone;
 (Z)-4-chlorostyryl-4-fluorobenzylsulfone; (Z)-4-fluorostyryl-4-
 chlorobenzylsulfone; (Z)-4-bromostyryl-4-chlorobenzylsulfone; and (Z)-4-
 bromostyryl-4-fluorobenzylsulfone.

15 According to another embodiment, the cytoprotective α,β
 unsaturated aryl sulfone compound is a compound of the formula VI:



wherein

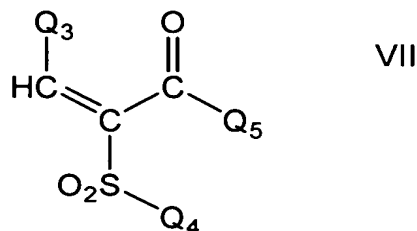
R_1 , R_2 , R_3 , and R_4 are independently selected from the group
 consisting of hydrogen, halogen, C1-8 alkyl, C1-8 alkoxy, nitro, cyano,
 20 carboxyl, hydroxyl, and trifluoromethyl.

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In one embodiment, R_1 in formula VI is selected from the group consisting of hydrogen, chlorine, fluorine and bromine; and R_2 , R_3 and R_4 are hydrogen.

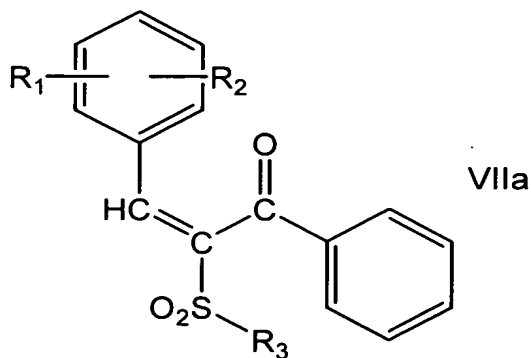
According to yet another embodiment, the cytoprotective α,β unsaturated aryl sulfone compound is a compound of the formula VII:



wherein

Q_3 , Q_4 and Q_5 are independently selected from the group consisting of phenyl and mono-, di-, tri-, tetra- and penta-substituted phenyl where the substituents, which may be the same or different, are independently selected from the group consisting of halogen, C1-C8 alkyl, C1-C8 alkoxy, nitro, cyano, carboxy, hydroxy, phosphonato, amino, sulfamyl, acetoxy, dimethylamino(C2-C6 alkoxy), C1-C6 trifluoroalkoxy and trifluoromethyl.

According to one sub-embodiment of formula VII, the cytoprotective α,β unsaturated aryl sulfone compound is a compound of the formula VIIa:



wherein

R₁ and R₂ are independently selected from the group consisting of hydrogen, halogen, C1-C8 alkyl, C1-8 alkoxy, nitro, cyano, carboxyl, hydroxyl, and trifluoromethyl; and

5 R₃ is selected from the group consisting of unsubstituted phenyl, mono-substituted phenyl and di-substituted phenyl, the substituents on the phenyl ring being independently selected from the group consisting of halogen and C1-8 alkyl.

10 Preferably, R₁ in formula VIIa is selected from the group consisting of fluorine and bromine; R₂ is hydrogen; and R₃ is selected from the group consisting of 2-chlorophenyl, 4-chlorophenyl, 4-fluorophenyl, and 2-nitrophenyl.

A preferred cytoprotective styryl sulfone according to formula VIIa is the compound wherein R₁ is fluorine, R₂ is hydrogen and R₃ is phenyl, that is, the compound 2-(phenylsulfonyl)-1-phenyl-3-(4-fluorophenyl)-2-propen-1-one.

By "dimethylamino(C2-C6 alkoxy)" is meant $(\text{CH}_3)_2\text{N}(\text{CH}_2)_n\text{O}-$ wherein n is from 2 to 6. Preferably, n is 2 or 3. Most preferably, n is 2, that is, the group is the dimethylaminoethoxy group, that is, $(\text{CH}_3)_2\text{NCH}_2\text{CH}_2\text{O}-$.

By “phosphonato” is meant the group $-\text{PO}(\text{OH})_2$.

By "sulfamyl" is meant the group $-\text{SO}_2\text{NH}_2$.

Where a substituent on an aryl nucleus is an alkoxy group, the carbon chain may be branched or straight, with straight being preferred. Preferably, the alkoxy groups comprise C1-C6 alkoxy, more preferably C1-C4 alkoxy, most preferably methoxy.

Description of the Figures

Fig. 1 shows the plating efficiency of normal human fibroblasts (HFL-1) treated with various concentrations of the styryl sulfone (E)-4-fluorostyryl-4-chlorobenzylsulfone. The cells were incubated with the

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indicated concentration of the styryl sulfone for 24 hours, washed three times and harvested by trypsinization. Cells were plated at various dilutions to determine colony-forming ability.

Fig. 2 shows the effect of long term exposure of HFL-1 to (E)-4-fluorostyryl-4-chlorobenzylsulfone. Cells were exposed to either 2.5 or 5.0 μ M of the styryl sulfone for 96 hours and counted.

Fig. 3 is a graph of the effect of paclitaxel on HFL-1 cells which were either pre-treated with (E)-4-fluorostyryl-4-chlorobenzylsulfone and then exposed to paclitaxel, or treated simultaneously with both agents. Cells were enumerated 96 hours after exposure to paclitaxel.

Fig. 4 is a plot of the effect of vincristine on HFL-1 cells. Vincristine toxicity is abrogated by styryl sulfone treatment. Normal HFL cells were treated with 0 to 0.250 nM vincristine and 2.0 μ M (E)-4-fluorostyryl-4-chlorobenzylsulfone as indicated. Cell viability was assessed 96 hours after vincristine was added. "V", vincristine alone; "A - V", styryl sulfone followed by vincristine 24 hours later; "A + V", simultaneous styryl sulfone and vincristine treatment; "V - A", vincristine followed by styryl sulfone 24 hours later.

Fig. 5 shows the effect of the styryl sulfone (E)-4-fluorostyryl-4-chlorobenzylsulfone in protecting mice from paclitaxel cytotoxicity. The styryl sulfone was given 24 hours before paclitaxel, 4 hours before paclitaxel, or simultaneously with paclitaxel. Control animals received paclitaxel alone or styryl sulfone alone. Mortality was assessed 48 after paclitaxel injection.

Fig. 6 is similar to Fig. 5, except that mortality was assessed 144 hours post paclitaxel administration.

Detailed Description of the Invention

According to the present invention, certain α,β unsaturated aryl sulfones are administered with the aim of reducing or eliminating

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adverse effects of anticancer treatment with chemotherapeutic agents which comprise mitotic phase cell cycle inhibitors.

The usual description of the cell cycle describes the cycle in terms of a series of phases - interphase and M (mitotic) phase - and the subdivision of interphase into the times when DNA synthesis is proceeding, known as the S-phase (for synthesis phase), and the gaps that separate the S-phase from mitosis. G1 is the gap after mitosis but before DNA synthesis starts, and G2 is the gap after DNA synthesis is complete before mitosis and cell division. Interphase is thus composed of successive G1, S and G2 phases, and normally comprises 90% or more of the total cell cycle time. The M phase consists of nuclear division (mitosis) and cytoplasmic division (cytokinesis). During the early part of the M phase, the replicated chromosomes condense from their extended interphase condition. The nuclear envelope breaks down, and each chromosome undergoes movements that result in the separation of pairs of sister chromatids as the nuclear contents are divided. Two new nuclear envelopes then form, and the cytoplasm divides to generate two daughter cells, each with a single nucleus. This process of cytokinesis terminates the M phase and marks the beginning of the interphase of the next cell cycle. The daughter cells resulting from completion of the M phase begin the interphase of a new cycle.

By "mitotic phase cell cycle inhibitor" is meant a chemical agent whose mechanism of action includes inhibition of a cell's passage through any portion of the mitotic (M) phase of the cell cycle. Such agents include, by way of example and not limitation, taxanes, such as paclitaxel and its analogs; vinca alkaloids such as vincristine and vinblastine; colchicine; estramustine; and naturally occurring macrolides such as rhizoxin, maytansine, ansamitocin P-3, phomopsin A, dolastatin 10 and halichondrin B.

Paclitaxel is an anti-mitotic drug presently used as an initial treatment for ovarian, breast and lung cancer, with moderate success.

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Vincristine is a well-established anti-mitotic drug widely used for the treatment of breast cancer, Hodgkin's lymphoma and childhood cancers.

The topoisomerases constitute a group of enzymes that catalyze the conversion of DNA from one topological form to another by introducing transient breaks in one or both strands of a DNA duplex. Topological isomers are molecules that differ only in their state of supercoiling. Type I topoisomerase cuts one strand of DNA and relaxes negatively supercoiled DNA, but does not act on positively supercoiled DNA. Type II topoisomerase cuts both strands of DNA and increases the degree of negative supercoiling in DNA. By "topoisomerase inhibitor" is meant a chemical agent whose mechanism of action includes interfering with the function of a topoisomerase.

Inhibitors of topoisomerase I include, for example, adriamycin and etoposide. Inhibitors of topoisomerase II include, for example, camptothecin, irinotecan and topotecan.

The α,β unsaturated aryl sulfones differ from other known cytoprotective agents in that they not only protect normal cells, but are also operationally cytotoxic in tumor cells. In normal cells, the α,β unsaturated aryl sulfones induce a reversible resting state rendering the normal cells relatively refractory to the cytotoxic effect of mitotic phase cell cycle inhibitors and topoisomerase inhibitors. Data indicating the cytotoxic effect of the α,β unsaturated aryl sulfone compounds on tumor cells is set forth in PCT/US/98/20580; PCT/US00/08565; and in the following commonly assigned U.S. patent applications: 60/127,683, filed April 2, 1999; 60/143,975, filed July 15, 1999; 09/282,855, filed March 31, 1999; and 60/197,368, filed April 14, 2000. The entire disclosures of the aforesaid PCT and U.S. patent applications are incorporated herein by reference. It is believed that the α,β unsaturated aryl sulfones, and particularly the styryl sulfones, are the first compounds which are both cytoprotective in normal cells and toxic in cancer cells.

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In tumored cells, α,β unsaturated aryl sulfones exhibit contrasting characteristics. They are cytotoxic at a low concentration rather than being reversible cytostatic, even at high concentrations. The α,β unsaturated aryl sulfones impact on normal cells is to cause a transitory cycling arrest. Paclitaxel cytotoxic effects include proinflammatory cytokine release of IL-1, TNF, and nitric oxide (Kirikae *et al. Biochem Biophys Res Commun.* 245:698-704, 1998; White *et al. Cancer Immunol. Immunoth.* 46:104-112, 1998). Its major effect is mitotic blockade, and induction of c-Jun NH α -terminal kinase/AP-1 death pathways. (Lee *et al., J. Biol Chem* 273:28253-28260, 1998; Amato *et al., Cancer Res.* 58:241-247, 1998). As cytoprotective agents against the toxicity of paclitaxel, the α,β unsaturated aryl sulfones presumably also induce a direct or indirect

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biochemical blockade of macrophage/monocyte response to paclitaxel in normal cells, and interfere with the cell death signaling pathway.

The schedule of administration of the cytotoxic drug, i.e., mitotic phase cell cycle inhibitor or topoisomerase inhibitor, can be any schedule with the stipulation that α,β unsaturated aryl sulfone is administered prior to the cytotoxic drug. The sulfone should be administered far enough in advance of the cytotoxic drug such that the former is able to reach the normal cells of the patient in sufficient concentration to exert a cytoprotective effect on the normal cells. In one embodiment, the sulfone is administered at least about 4 hours before administration of the cytotoxic drug. The sulfone may be administered as much as about 48 hours, preferably no more than about 36 hours, prior to administration of the cytotoxic drug. Most preferably, the sulfone is administered about 24 hours before the cytotoxic drug. The sulfone may be administered more or less than 24 hours before the cytotoxic effect, but the protective effect of the α,β unsaturated aryl sulfones is greatest when administered about 24 hours before the cytotoxic drug. One or more cytotoxic drugs may be administered. Similarly, one or more α,β unsaturated aryl sulfones may be combined.

Where the cytotoxic drug or drugs is administered in serial fashion, it may prove practical to intercalate sulfones within the schedule with the caveat that a 4-48 hour period, preferably a 12-36 hour period, most preferably a 24 hour period, separates administration of the two drug types. This strategy will yield partial to complete eradication of cytotoxic drug side effects without affecting anticancer activity.

For example, the mitotic inhibitor may be given daily, or every fourth day, or every twenty-first day. The sulfone may be given 24 hours previous to each round of inhibitor administration, both as a cytoprotective agent and as an antitumor agent.

It may be appreciated that by "administered" is meant the act of making drug available to the patient such that a physiological effect is

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dosage, is contemplated according to the present invention due to the protection of the normal cells afforded by the α,β unsaturated aryl sulfones. Thus the cytoprotective effect of the sulfone may permit the physician in some circumstances to increase the dosage of the mitotic phase cell cycle inhibitor above levels presently recommended.

While the sulfone and the mitotic phase cell cycle inhibitor may be administered by different routes, the same route of administration is preferred.

The α,β unsaturated aryl sulfones may take the form or pharmaceutically acceptable salts. The term "pharmaceutically acceptable salts", embraces salts commonly used to form alkali metal salts and to form addition salts of free acids or free bases. The nature of the salt is not critical, provided that it is pharmaceutically-acceptable. Suitable pharmaceutically acceptable acid addition salts may be prepared from an inorganic acid or from an organic acid. Examples of such inorganic acids are hydrochloric, hydrobromic, hydroiodic, nitric, carbonic, sulfuric and phosphoric acid. Appropriate organic acids may be selected from aliphatic, cycloaliphatic, aromatic, araliphatic, heterocyclic, carboxylic and sulfonic classes of organic acids, example of which are formic, acetic, propionic, succinic, glycolic, gluconic, lactic, malic, tartaric, citric, ascorbic, glucuronic, maleic, fumaric, pyruvic, aspartic, glutamic, benzoic, anthranilic, mesylic, salicylic, 4-hydroxybenzoic, phenylacetic, mandelic, embonic (pamoic), methanesulfonic, ethanesulfonic, benzenesulfonic, pantothenic, 2-hydroxyethanesulfonic, toluenesulfonic, sulfanilic, cyclohexylaminosulfonic, stearic, algenic, beta-hydroxybutyric, galactaric and galacturonic acid. Suitable pharmaceutically acceptable base addition salts include metallic salts made from calcium, lithium, magnesium, potassium, sodium and zinc or organic salts made from N,N'-dibenzylethylenediamine, chlorprocaine, choline, diethanolamine, ethylenediamine, meglumine (N-methylglucamine) and procaine. All of these salts may be prepared by conventional means

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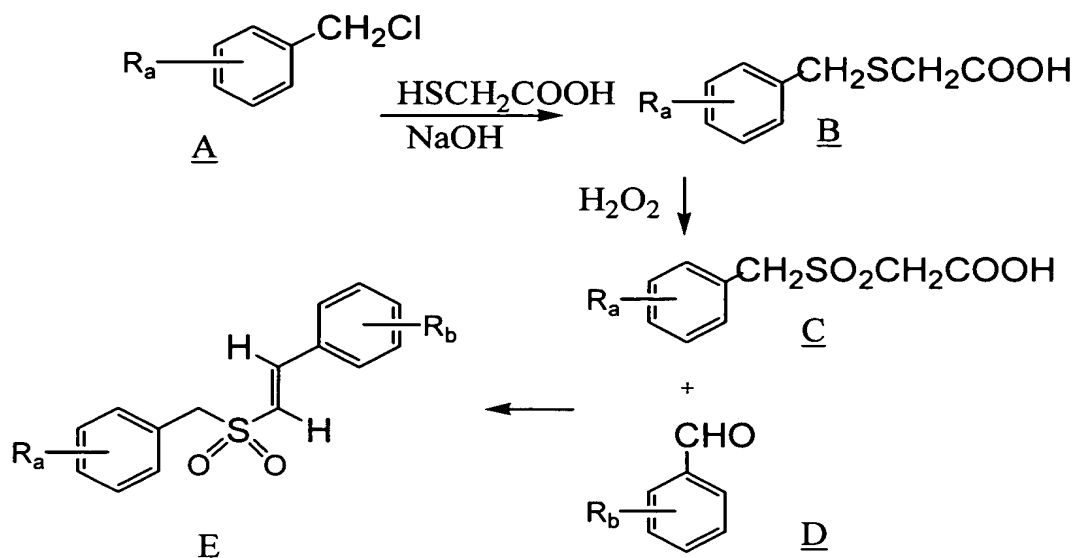
from the corresponding α,β unsaturated aryl sulfone by reacting, for example, the appropriate acid or base with the sulfone compound.

The α,β unsaturated aryl sulfones are characterized by cis-trans isomerism resulting from the presence of one or more double bonds. The compounds are named according to the Cahn-Ingold-Prelog system, the IUPAC 1974 Recommendations, Section E: Stereochemistry, in *Nomenclature of Organic Chemistry*, John Wiley & Sons, Inc., New York, NY, 4th ed., 1992, p. 127-138. Stearic relations around a double bond are designated as “Z” or “E”.

(E)- α,β unsaturated aryl sulfones may be prepared by Knoevenagel condensation of aromatic aldehydes with benzylsulfonyl acetic acids or arylsulfonyl acetic acids. The procedure is described by Reddy *et al.*, *Acta. Chim. Hung.* **115**:269-71 (1984); Reddy *et al.*, *Sulfur Letters* **13**:83-90 (1991); Reddy *et al.*, *Synthesis* No. 4, 322-23 (1984); and Reddy *et al.*, *Sulfur Letters* **7**:43-48 (1987), the entire disclosures of which are incorporated herein by reference.

According to the Scheme 1 below, R_a and R_b each represent from zero to five substituents on the depicted aromatic nucleus. For purposes of illustration, and not limitation, the aryl groups are represented as phenyl groups, that is, the synthesis is exemplified by the preparation of styryl benzylsulfones. Accordingly, the benzyl thioacetic acid B is formed by the reaction of sodium thioglycollate and a benzyl chloride A. The benzyl thioacetic acid B is then oxidized with 30% hydrogen peroxide to give a corresponding benzylsulfonyl acetic acid C. Condensation of the benzylsulfonyl acetic acid C with an aromatic aldehyde D via a Knoevenagel reaction in the presence of benzylamine and glacial acetic acid yields the desired (E)-styryl benzylsulfone E.

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Scheme 1

The following is a more detailed two-part synthesis procedure for preparing (E)-styryl benzylsulfones according to the above scheme.

General Procedure 1: Synthesis (E)-Styryl Benzylsulfones

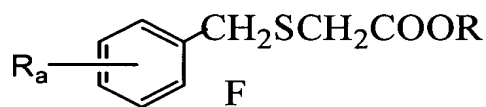
Part A. To a solution of (8g, 0.2 mol) sodium hydroxide in methanol (200 ml), thioglycolic acid (0.1 mol) is added slowly and the precipitate formed is dissolved by stirring the contents of the flask. Then an appropriately substituted benzyl chloride (0.1 mol) is added stepwise and the reaction mixture is refluxed for 2-3 hours. The cooled contents are poured onto crushed ice and neutralized with dilute hydrochloric acid (200 ml). The resulting corresponding benzylthioacetic acid (0.1 mol) is subjected to oxidation with 30% hydrogen peroxide (0.12 mol) in glacial acetic acid (125 ml) by refluxing for 1 hour. The contents are cooled and poured onto crushed ice. The separated solid is recrystallized from hot water to give the corresponding pure benzylsulfonylacetic acid.

Part B. A mixture of the benzylsulfonyl acetic acid (10 mmol), an appropriately substituted aromatic aldehyde (10 mmol), and benzylamine

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(200 ml) in glacial acetic acid (12 ml) is refluxed for 2-3 hours. The contents are cooled and treated with cold ether (50 ml). Any product precipitated out is separated by filtration. The filtrate is diluted with more ether and washed successively with a saturated solution of sodium bicarbonate (20 ml), sodium bisulfite (20 ml), dilute hydrochloric acid (20 ml) and finally with water (35 ml). Evaporation of the dried ethereal layer yields styryl benzylsulfones as a solid material.

According to an alternative to Part A, the appropriate benzylsulfonylacetic acids may be generated by substituting a thioglycollate
10 HSCH₂COOR for thioglycollic acid, where R is an alkyl group, typically C1-
C6 alkyl. This leads to the formation of the alkylbenzylthioacetate
intermediate (F),



which is then converted to the corresponding benzyl thioacetic acid **B** by alkaline or acid hydrolysis.

15 (E)-styryl phenyl sulfones (formula I: n=zero; Q₁, Q₂ = substituted or unsubstituted phenyl) are prepared according to the method of General Procedure 1, replacing the benzylsulfonyl acetic acid in Part B with the appropriate substituted or unsubstituted phenylsulfonyl acetic acid.

(Z)-Styryl benzylsulfones are prepared by the nucleophilic addition of the appropriate thiols to substituted phenylacetylene with subsequent oxidation of the resulting sulfide by hydrogen peroxide to yield the (Z)-styryl benzylsulfone. The procedure is generally described by Reddy et al., Sulfur Letters 13:83-90 (1991), the entire disclosure of which is incorporated herein as a reference.

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In the first step of the (Z)-styryl benzylsulfones synthesis, the sodium salt of benzyl mercaptan or the appropriate substituted benzyl mercaptan is allowed to react with phenylacetylene or the appropriate substituted phenylacetylene forming the pure (Z)-isomer of the corresponding styryl benzylsulfide in good yield.

In the second step of the synthesis, the (Z)-styryl benzylsulfide intermediate is oxidized to the corresponding sulfone in the pure (Z)-isomeric form by treatment with hydrogen peroxide.

The following is a more detailed two-part synthesis procedure for preparing (Z)-styryl benzylsulfones:

Procedure 2: Synthesis of (Z)-Styryl Benzylsulfones

Part A. To a refluxing methanolic solution of substituted or unsubstituted sodium benzylthiolate prepared from 460 mg (0.02g atom) of (i) sodium, (ii) substituted or unsubstituted benzyl mercaptan (0.02 mol) and (iii) 80 ml of absolute methanol, is added freshly distilled substituted or unsubstituted phenylacetylene. The mixture is refluxed for 20 hours, cooled and then poured on crushed ice. The crude product is filtered, dried and recrystallized from methanol or aqueous methanol to yield a pure (Z)-styryl benzylsulfide.

Part B. An ice cold solution of the (Z)-styryl benzylsulfide (3.0g) in 30 ml of glacial acetic acid is treated with 7.5 ml of 30% hydrogen peroxide. The reaction mixture is refluxed for 1 hour and then poured on crushed ice. The separated solid is filtered, dried, and recrystallized from 2-propanol to yield the pure (Z)-styryl benzylsulfone. The purity of the compounds is ascertained by thin layer chromatography and geometrical configuration is assigned by analysis of infrared and nuclear magnetic resonance spectral data.

The bis(styryl) sulfones of formula VI are prepared according to Procedure 3:

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Synthesis of (E)(E)- and (E)(Z)-bis(Styryl) Sulfones

25 (E),(E)-bis(styryl)sulfones are prepared following the same procedure as described above with exception that sulfonyldiacetic acid is used in place of (Z)-styrylsulfonylacetic acid, and twice the amount of aromatic aldehyde (20 mmol) is used.

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The styryl sulfones of formula VII, which are systematically identified as 2-(phenylsulfonyl)-1-phenyl-3-phenyl-2-propen-1-ones, may be prepared according to either Method A or Method B of Procedure 4:

Procedure 4

5 **Synthesis of 2-(Phenylsulfonyl)-1-phenyl-3-phenyl-2-propen-1-ones**

These compounds are synthesized by two methods which employ different reaction conditions, solvents and catalysts.

10 **Method A:** Phenacyl aryl sulfones are made by refluxing α -bromoacetophenones (0.05 mol) and sodium arylsulfonates (0.05 mol) in absolute ethanol (200 ml) for 6-8 hours. The product which separates on cooling is filtered and washed several times with water to remove sodium bromide. The product is then recrystallized from ethanol: phenacyl-phenyl sulfone, m.p. 90-91°C; phenacyl-p-fluorophenyl sulfone, m.p. 148-149°C; phenacyl-p-bromophenyl sulfone, m.p. 121-122°C; phenacyl-p-methoxy-phenyl sulfone, m.p. 104-105°C; p-nitrophenacyl-phenyl sulfone, m.p. 136-137°C.

15 A solution of phenacyl aryl sulfone (0.01 mol) in acetic acid (10 ml) is mixed with an aldehyde (0.01 mol) and benzylamine (0.02 ml) and refluxed for 3 hours. The solution is cooled and dry ether (50 ml) is added.

20 The ethereal solution is washed successively with dilute hydrochloric acid, aqueous 10% NaOH, saturated NaHSO₃ solution and water. Evaporation of the dried ethereal layer gives a solid product which is purified by recrystallization.

25 **Method B:** Dry tetrahydrofuran (200 ml) is taken in a 500 ml conical flask flushed with nitrogen. To this, a solution of titanium (IV) chloride (11 ml, 0.01 mol) in absolute carbon tetrachloride is added dropwise with continuous stirring. The contents of the flask are maintained at -20°C throughout the course of the addition. A mixture of phenacyl aryl sulfone (0.01 mol) and aromatic aldehyde (0.01 mol) is added to the reaction

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10

(E)-styryl phenyl sulfone

15

(E)-4-chlorostyryl phenyl sulfone

20

(E)-2,4-dichlorostyryl phenyl sulfone

25

(E)-4-bromostyryl phenyl sulfone

5 The title compound was obtained in 78-80% yield.

(E)-4-chlorostyryl 4-chlorophenyl sulfone

10 title compound was obtained in 70-72% yield.

(E)-4-methylstyryl 4-chlorophenyl sulfone

15 The title compound was obtained in 60-64% yield.

(E)-4-methoxystyryl 4-chlorophenyl sulfone

20 The title compound was obtained in 68-70% yield.

(E)-4-bromostyryl 4-chlorophenyl sulfone

25 title compound was obtained in 80% yield.

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Synthesis Example 9

(E)-2-chlorostyryl benzyl sulfone

A solution of benzyl sulfonylacetic acid (0.01 mol) and 2-chlorobenzaldehyde (0.01 mol) was subjected to Procedure 1, Part B.

5 The title compound was obtained in 72% yield.

Synthesis Example 10

E-4-chlorostyryl benzyl sulfone

A solution of benzyl sulfonylacetic acid (0.01 mol) and 4-chlorobenzaldehyde (0.01 mol) was subjected to Procedure 1, Part B.

10 The title compound was obtained in 78% yield.

Synthesis Example 11

E-4-fluorostyryl 4-chlorobenzyl sulfone

A solution of 4-chlorobenzyl sulfonylacetic acid (0.01 mol) and 4-fluorobenzaldehyde (0.01 mol) was subjected to Procedure 1, Part B.

15 The title compound was obtained in 72% yield.

Synthesis Example 12

(E)-4-chlorostyryl 4-chlorobenzyl sulfone

A solution of 4-chlorobenzyl sulfonylacetic acid (0.01 mol) and 4-chlorobenzaldehyde (0.01 mol) was subjected to Procedure 1, Part B.

20 The title compound was obtained in 80% yield.

Synthesis Example 13

(E)-4-fluorostyryl 4-fluorobenzyl sulfone

A solution of 4-fluorobenzyl sulfonylacetic acid (0.01 mol) and 4-fluorobenzaldehyde (0.01 mol) was subjected to Procedure 1, Part B.

25 The title compound was obtained in 73% yield.

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Synthesis Example 14

(E)-2,4-difluorostyryl 4-fluorobenzyl sulfone

A solution of 4-fluorobenzyl sulfonylacetic acid (0.01 mol) and 2,4-difluorobenzaldehyde (0.01 mol) was subjected to Procedure 1, Part B.

5 The title compound was obtained in 68% yield.

Synthesis Example 15

(E)-4-fluorostyryl 4-bromobenzyl sulfone

A solution of 4-bromobenzyl sulfonylacetic acid (0.01 mol) and 4-fluorobenzaldehyde (0.01 mol) was subjected to Procedure 1, Part B.

10 The title compound was obtained in 82% yield.

Synthesis Example 16

(E)-4-bromostyryl 4-bromobenzyl sulfone

A solution of 4-bromobenzyl sulfonylacetic acid (0.01 mol) and 4-bromobenzaldehyde (0.01 mol) was subjected to Procedure 1, Part B.

15 The title compound was obtained in 88% yield.

Synthesis Example 17

(E)-4-bromostyryl 4-fluorobenzyl sulfone

A solution of 4-fluorobenzyl sulfonylacetic acid (0.01 mol) and 4-bromobenzaldehyde (0.01 mol) was subjected to Procedure 1, Part B. The

20 title compound was obtained in 82% yield.

Synthesis Example 18

(E)-4-chlorostyryl 4-bromobenzyl sulfone

A solution of 4-bromobenzylsulfonyl acetic acid (0.01 mol) and 4-chlorobenzaldehyde (0.01 mol) was subjected to Procedure 1, Part B. The

25 title compound was obtained in 88% yield.

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Synthesis Example 19

(E)-4-bromostyryl 4-chlorobenzyl sulfone

A solution of 4-chlorobenzylsulfonyl acetic acid (0.01 mol) and 4-bromobenzaldehyde (0.01 mol) was subjected to Procedure 1, Part B. The title compound was obtained in 92% yield.

Infrared and nuclear magnetic resonance spectroscopy analyses of the compounds of Synthesis Examples 1 through 19 are set forth in Table 1:

Table 1: IR and NMR Spectroscopy

Syn. Ex.	IR (KR pellet)		NMR (CDCl ₃) (δ ppm)
	νC=C	νSO ₂	
1	1638	1380,1140	6.81(1H, d, J _{H,H} =15.6), 7.2-7.8(m,10H), 7.49(1H,d)
2	1627	1368,1155	6.88 (1H, d, J _{H,H} =15.2), 7.15-7.9(m,9h), 7.54(1H,d)
3	1635	1370,1140	6.92(1H, d, J _{H,H} =15.6), 7.3-7.85(m,9H), 7.62(1H,d)
4	1642	1355,1142	6.90(1H, d, J _{H,H} =15.4), 7.25-7.9(m,9H), 7.58(1H,d)
5	1645	1328,1126	6.86(1H, d, J _{H,H} =15.6), 7.30-7.75(m,8H), 7.55(1H,d)
6	1650	1344,1116	2.45(3H, s),6.83(1H, d, J _{H,H} =15.8), 7.25-7.85(m,8H), 7.48(1H,d)
7	1658	1320,1128	3.85(3H, s),6.85(1H, d, J _{H,H} =15.4), 7.28-7.82(m,8H), 7.60(1H,d)
8	1660	1311,1148	6.84(1H, d, J _{H,H} =15.6), 7.25-7.8(m,8H), 7.60(1H,d)
9	1638	1318,1140	4.30(2H,s),6.81(1H, d, J _{H,H} =15.6), 7.30-7.75(m,9H), 7.58(1H)
10	1642	1312,1140	4.34(2H,s),6.78(1H, d, J _{H,H} =15.7), 7.26-7.85(m,9H), 7.54(1H)
11	1650	1305,1150	4.32(2H,s),6.82(1H, d, J _{H,H} =16.0), 7.22-7.76(m,8H), 7.52(1H)
12	1658	1316,1132	4.38(2H,s),6.86(1H, d, J _{H,H} =16.2), 7.26-7.85(m,8H), 7.58(1H)
13	1640	1307,1132	4.44(2H,s),6.84(1H, d, J _{H,H} =15.8), 7.20-7.78(m,8H), 7.58(1H)
14	1646	1326,1145	4.40(2H,s),6.88(1H, d, J _{H,H} =15.6), 7.33-7.72(m,7H), 7.58(1H)
15	1660	1330,1144	4.46(2H,s),6.90(1H, d, J _{H,H} =16.2), 7.24-7.78(m,8H), 7.58(1H)

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16	1658	1316,1132	4.38(2H,s),6.76(1H, d, $J_{H,H}=16.3$), 7.36-7.84(m,8H), 7.58(1H)
17	1644	1314,1152	4.43(2H,s),6.84(1H, d, $J_{H,H}=15.8$), 7.28-7.76(m,8H), 7.60(1H)
18	1652	1321,1148	4.42(2H,s),6.78(1H, d, $J_{H,H}=16.0$), 7.34-7.80(m,8H), 7.54(1H)
19	1638	1330,1138	4.38(2H,s),6.82(1H, d, $J_{H,H}=15.6$), 7.28-7.78(m,8H), 7.55(1H)

5

Synthesis Example 20**(E)-4-Fluorostyryl-4-trifluoromethylbenzylsulfone**

A solution of 4-trifluoromethylbenzylsulfonylacetic acid (10 mmol) and 4-fluorobenzaldehyde (10mmol) was subjected to the Procedure 1, Part B. The title compound melting point 166-168°C, was obtained in 82% yield.

10

Synthesis Example 21**(E)-4-Chlorostyryl-4-trifluoromethylbenzylsulfone**

A solution of 4-trifluoromethylbenzylsulfonylacetic acid (10 mmol) and 4-chlorobenzaldehyde (10 mmol) was subjected to the Procedure 1, Part B. The title compound, melting point 164-168°C, was obtained in 88% yield.

15

Synthesis Example 22**(E)-4-Bromostyryl-4-trifluoromethylbenzylsulfone**

A solution of 4-trifluoromethylbenzylsulfonylacetic acid (10 mmol) and 4-bromobenzaldehyde (10 mmol) was subjected to the Procedure 1, Part B. The title compound, melting point 181-183°C, was obtained in 85% yield.

20

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Synthesis Example 23**(E)-4-Fluorostyryl-2,4-dichlorobenzylsulfone**

A solution of 2,4-dichlorobenzylsulfonyl acid (10 mmol) and 4-fluorobenzaldehyde (10 mmol) was subjected to the Procedure 1, Part B.

5 The title compound, melting point 146-148°C, was obtained in 78% yield.

Synthesis Example 24**(E)-4-Chlorostyryl-2,4-dichlorobenzylsulfone**

A solution of 2,4-dichlorobenzylsulfonylacetic acid (10 mmol) and 4-chlorobenzaldehyde (10 mmol) was subjected to the Procedure 1, Part B.

10 The title compound, melting point 148-149°C, was obtained in 84% yield.

Synthesis Example 25**(E)-4-Fluorostyryl-3,4-dichlorobenzylsulfone**

A solution of 3,4-dichlorobenzylsulfonylacetic acid (10 mmol) and 4-fluorobenzaldehyde (10 mmol) was subjected to the Procedure 1, Part B.

15 The title compound, melting point 120-122°C, was obtained in 82% yield.

Synthesis Example 26**(E)-4-Chlorostyryl-3,4-dichlorobenzylsulfone**

A solution of 3,4-dichlorobenzylsulfonylacetic acid (10 mmol) and 4-chlorobenzaldehyde (10 mmol) was subjected to the Procedure 1, Part B.

20 The title compound, melting point 149-151°C, was obtained in 86% yield.

Synthesis Example 27**(E)-4-Bromostyryl-3,4-dichlorobenzylsulfone**

A solution of 3,4-dichlorobenzylsulfonylacetic acid (10 mmol) and 4-bromobenzaldehyde (10 mmol) was subjected to the Procedure 1, Part B.

25 The title compound, melting point 154-155°C, was obtained in 84% yield.

(E)-4-Bromostyryl-4-nitrobenzylsulfone

5 The title compound, melting point 160-161°C, was obtained in 76% yield.

(E)-4-Fluorostyryl-4-cyanobenzylsulfone

10 The title compound, melting point 150-151°C, was obtained in 82% yield.

(E)-4-Chlorostyryl-4-cyanobenzylsulfone

15 The title compound, melting point 173-177°C, was obtained in 86% yield.

(E)-4-Bromostyryl-4-cyanobenzylsulfone

20 The title compound, melting point 183-184°C, was obtained in 77% yield.

(E)-3,4-Difluorostyryl-4-chlorobenzylsulfone

25 compound, melting point 204-205°C, was obtained in 73% yield.

(E)-3-Chloro-4-fluorostyryl-4-chlorobenzylsulfone

5 The title compound, melting point 181-183°C, was obtained in 78% yield.

(E)-2-Chloro-4-fluorostyryl-4-chlorobenzylsulfone

10 The title compound, melting point 149-150°C, was obtained in 68% yield.

(E)-2,4-Dichlorostyryl-4-chlorobenzylsulfone

15 compound, melting point 164-165°C, was obtained in 78% yield.

(E)-3,4-Dichlorostyryl-4-chlorobenzylsulfone

20 B. The title compound, melting point 170-171°C, was obtained in 73% yield.

(E)-2,3-Dichlorostyryl-4-chlorobenzylsulfone

25 dichlorobenzaldehyde (10 mmol) was subjected to the Procedure 1, part B. The title compound, melting point 170-171°C, was obtained in 72% yield.

Synthesis Example 38**(Z)-styryl benzylsulfone**

A solution of phenylacetylene (0.02 mol) and benzyl mercaptan (0.02 mol) and metallic sodium (0.02g atom) was subjected to the Procedure 2, part A, to form (Z)-styryl benzylsulfide. The title compound was obtained in 65% yield by oxidation of the sulfide according to the Procedure 2, part B. ¹HNMR (CDCl₃) δ4.50 (2H, s), 6.65 (1H, d, J_{H,H} = 11.2), 7.18-7.74 (10H aromatic + 1H ethylenic).

Synthesis Example 39**(Z)-styryl 4-chlorobenzylsulfone**

A solution of phenylacetylene (0.02 mol) and 4-chlorobenzyl mercaptan (0.02 mol) and metallic sodium (0.02g atom) was subjected to Procedure 2 to form (Z)-styryl 4-chlorobenzylsulfide. The title compound was obtained in 72% yield following oxidation. ¹HNMR (CDCl₃) δ4.56 (2H, s), 6.68 (1H, d, J_{H,H} = 11.8), 7.20-7.64 (9H aromatic + 1H ethylenic).

Synthesis Example 40**(Z)-styryl 2-chlorobenzylsulfone**

A solution of phenylacetylene (0.02 mol) and 2-chlorobenzyl mercaptan (0.02 mol) and metallic sodium (0.02g atom) was subjected to Procedure 2 to form (Z)-styryl 2-chlorobenzylsulfide. The title compound was obtained in 68% yield following oxidation. ¹HNMR (CDCl₃) δ4.50 (2H, s), 6.65 (1H, d, J_{H,H} = 12.0), 7.18-7.74 (9H aromatic + 1H ethylenic).

Synthesis Example 41**(Z)-styryl 4-fluorobenzylsulfone**

A solution of phenylacetylene (0.02 mol) and 4-fluorobenzyl mercaptan (0.02 mol) and metallic sodium (0.02g atom) was subjected to Procedure 2 to form (Z)-styryl 4-fluorobenzylsulfide. The title compound was obtained in 70% yield following oxidation. ¹HNMR (CDCl₃) δ4.58 (2H, s), 6.62 (1H, d, J_{H,H} = 11.86), 7.18-7.60 (9H aromatic + 1H ethylenic).

Synthesis Example 42**(Z)-4-chlorostyryl benzylsulfone**

A solution of 4-chlorophenylacetylene (0.02 mol) and benzyl mercaptan (0.02 mol) and metallic sodium (0.02g atom) was subjected to Procedure 2 to form (Z)-4-chlorostyryl benzylsulfide. The title compound was obtained in 74% yield following oxidation. ¹HNMR (CDCl₃) δ4.55 (2H, s), 6.66 (1H, d, J_{H,H} = 12.12), 7.16-7.65 (9H aromatic + 1H ethylenic).

Synthesis Example 43**(Z)-4-chlorostyryl 4-chlorobenzylsulfone**

A solution of 4-chlorophenylacetylene (0.02 mol) and 4-chlorobenzyl mercaptan (0.02 mol) and metallic sodium (0.02g atom) was subjected to Procedure 2 to form (Z)-4-chlorostyryl 4-chlorobenzylsulfide. The title compound was obtained in 76% yield following oxidation. ¹HNMR (CDCl₃) δ4.62 (2H, s), 6.68 (1H, d, J_{H,H} = 11.92), 7.18-7.60 (8H aromatic + 1H ethylenic).

Synthesis Example 44**(Z)-4-chlorostyryl 2-chlorobenzylsulfone**

A solution of 4-chlorophenylacetylene (0.02 mol) and 2-chlorobenzyl mercaptan (0.02 mol) and metallic sodium (0.02g atom) was subjected to Procedure 2 to form (Z)-4-chlorostyryl 2-chlorobenzylsulfide. The title compound was obtained in 73% yield following oxidation. ¹HNMR (CDCl₃) δ4.56 (2H, s), 6.70 (1H, d, J_{H,H} = 12.05), 7.18-7.64 (8H aromatic + 1H ethylenic).

Synthesis Example 45**(Z)-4-chlorostyryl 4-fluorobenzylsulfone**

A solution of 4-chlorophenylacetylene (0.02 mol) and 4-fluorobenzyl mercaptan (0.02 mol) and metallic sodium (0.02g atom) was subjected to Procedure 2 to form (Z)-4-chlorostyryl 4-fluorobenzylsulfide. The title

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compound was obtained in 82% yield following oxidation. ^1H NMR (CDCl_3) δ 4.60 (2H, s), 6.70 (1H, d, $J_{\text{H,H}} = 11.78$), 7.18-7.60 (8H aromatic + 1H ethylenic).

Synthesis Example 46

5 (Z)-4-fluorostyryl benzylsulfone

A solution of 4-fluorophenylacetylene (0.02 mol) and benzyl mercaptan (0.02 mol) and metallic sodium (0.02g atom) was subjected to Procedure 2 to form (Z)-4-fluorostyryl benzylsulfide. The title compound was obtained in 76% yield following oxidation. ^1H NMR (CDCl_3) δ 4.54 (2H, s), 6.68 (1H, d, $J_{\text{H,H}} = 11.94$), 7.12-7.58 (9H aromatic + 1H ethylenic).

Synthesis Example 47

(Z)-4-fluorostyryl 4-chlorobenzylsulfone

A solution of 4-fluorophenylacetylene (0.02 mol) and 4-chlorobenzyl mercaptan (0.02 mol) and metallic sodium (0.02g atom) was subjected to Procedure 2 to form (Z)-4-fluorostyryl 4-chlorobenzylsulfide. The title compound was obtained in 82% yield following oxidation. ^1H NMR (CDCl_3) δ 4.60 (2H, s), 6.68 (1H, d, $J_{\text{H,H}} = 11.84$), 7.18-7.60 (8H aromatic + 1H ethylenic).

Synthesis Example 48

20 (Z)-4-fluorostyryl 2-chlorobenzylsulfone

A solution of 4-fluorophenylacetylene (0.02 mol) and 2-chlorobenzyl mercaptan (0.02 mol) and metallic sodium (0.02g atom) was subjected to Procedure 2 to form (Z)-4-fluorostyryl 2-chlorobenzylsulfide. The title compound was obtained in 74% yield following oxidation. ^1H NMR (CDCl_3) δ 4.55 (2H, s), 6.66 (1H, d, $J_{\text{H,H}} = 11.94$), 7.20-7.65 (8H aromatic + 1H ethylenic).

(Z)-4-fluorostyryl 4-fluorobenzylsulfone

5

10 **(Z)-4-bromostyryl benzylsulfone**

15

(Z)-4-bromostyryl 4-chlorobenzylsulfone

20

25 **(Z)-4-bromostyryl 2-chlorobenzylsulfone**

25

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compound was obtained in 84% yield following oxidation. ^1H NMR (CDCl_3) δ 4.57 (2H, s), 6.70 (1H, d, $J_{\text{H,H}} = 11.58$), 7.18-7.58 (8H aromatic + 1H ethylenic).

Synthesis Example 53

5 (Z)-4-bromostyryl 4-fluorobenzylsulfone

A solution of 4-bromophenylacetylene (0.02 mol) and 4-fluorobenzyl mercaptan (0.02 mol) and metallic sodium (0.02g atom) was subjected to Procedure 2 to form (Z)-4-bromostyryl 4-fluorobenzylsulfide. The title compound was obtained in 78% yield following oxidation. ^1H NMR (CDCl_3) δ 4.58 (2H, s), 6.65 (1H, d, $J_{\text{H,H}} = 11.78$), 7.22-7.67 (8H aromatic + 1H ethylenic).

Synthesis Example 54

(Z)-4-methylstyryl benzylsulfone

A solution of 4-methylphenylacetylene (0.02 mol) and benzyl mercaptan (0.02 mol) and metallic sodium (0.02g atom) was subjected to Procedure 2 to form (Z)-4-methylstyryl benzylsulfide. The title compound was obtained in 70% yield following oxidation. ^1H NMR (CDCl_3) δ 2.48 (3H, s), 4.60 (2H, s), 6.68 (1H, d, $J_{\text{H,H}} = 11.94$), 7.20-7.65 (9H aromatic + 1H ethylenic).

Synthesis Example 55

20 (Z)-4-methylstyryl 4-chlorobenzylsulfone

A solution of 4-methylphenylacetylene (0.02 mol) and 4-chlorobenzyl mercaptan (0.02 mol) and metallic sodium (0.02g atom) was subjected to Procedure 2 to form (Z)-4-methylstyryl 4-chlorobenzylsulfide. The title compound was obtained in 74% yield following oxidation. ^1H NMR (CDCl_3) δ 2.46 (3H, s), 4.64 (2H, s), 6.75 (1H, d, $J_{\text{H,H}} = 12.21$), 7.18-7.57 (9H aromatic + 1H ethylenic).

Synthesis Example 56**(Z)-4-methylstyryl 2-chlorobenzylsulfone**

A solution of 4-methylphenylacetylene (0.02 mol) and 2-chlorobenzyl mercaptan (0.02 mol) and metallic sodium (0.02g atom) was subjected to Procedure 2 to form (Z)-4-methylstyryl 2-chlorobenzylsulfide. The title compound was obtained in 76% yield following oxidation. ¹HNMR (CDCl₃) δ2.50 (3H, s), 4.58 (2H, s), 6.80 (1H, d, J_{H,H} = 11.88), 7.20-7.63 (9H aromatic + 1H ethylenic).

Synthesis Example 57**(Z)-4-methylstyryl 4-fluorobenzylsulfone**

A solution of 4-methylphenylacetylene (0.02 mol) and 4-fluorobenzyl mercaptan (0.02 mol) and metallic sodium (0.02g atom) was subjected to Procedure 2 to form (Z)-4-methylstyryl 4-fluorobenzylsulfide. The title compound was obtained in 69% yield following oxidation. ¹HNMR (CDCl₃) δ2.46 (3H, s), 4.62 (2H, s), 6.78 (1H, d, J_{H,H} = 11.98), 7.18-7.59 (9H aromatic + 1H ethylenic)

The following additional (E)-α,β unsaturated aryl sulfones listed in Tables 3a and 3b were prepared by reacting the appropriate benzylsulfonyl acetic acid and benzaldehyde or arylaldehyde according to Procedure 1, Part B:

Table 3a

Syn. Ex.	M.P. (°C)	Yield (%)	Compound
58	134-136	55	(E)-2-nitrostyryl-4-fluorobenzylsulfone
59	170-173	64	(E)-3-nitrostyryl-4-fluorobenzylsulfone
60	151-152	61	(E)-4-nitrostyryl-4-fluorobenzylsulfone
61	96-98	54	(E)-2-trifluoromethylstyryl-4-fluorobenzylsulfone
62	117-119	55	(E)-3-trifluoromethylstyryl-4-fluorobenzylsulfone

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5	63	125-128	73	(E)-4-trifluoromethylstyryl-4-fluorobenzyisulfone
	64	108-112	52	(E)-2-trifluoromethyl-4-fluorostyryl-4-fluorobenzyisulfone
	65	128-132	58	(E)-2-nitrostyryl-4-chlorobenzyisulfone
	66	156-157	60	(E)-3-nitrostyryl-4-chlorobenzyisulfone
	67	189-191	61	(E)-4-nitrostyryl-4-chlorobenzyisulfone
10	68	100-101	55	(E)-2-trifluoromethylstyryl-4-chlorobenzyisulfone
	69	155-157	58	(E)-3-trifluoromethylstyryl-4-chlorobenzyisulfone
	70	164-166	59	(E)-4-trifluoromethylstyryl-4-chlorobenzyisulfone
	71	115-117	63	(E)-2-trifluoromethyl-4-fluorostyryl-4-chlorobenzyisulfone
	72	169-171	63	(E)-3-methyl-4-fluorostyryl-4-chlorobenzyisulfone
15	73	136-138	57	(E)-2-nitrostyryl-2,4-dichlorobenzyisulfone
	74	136-138	57	(E)-2-trifluoromethyl-4-fluorostyryl-2,4-dichlorobenzyisulfone
	75	131-132	63	(E)-2-nitrostyryl-4-bromobenzyisulfone
	76	168-170	56	(E)-3-nitrostyryl-4-bromobenzyisulfone
	77	205-207	67	(E)-4-nitrostyryl-4-bromobenzyisulfone
20	78	102-104	57	(E)-2-trifluoromethylstyryl-4-bromobenzyisulfone
	79	160-161	55	(E)-3-trifluoromethylstyryl-4-fluorobenzyisulfone
	80	174-175	62	(E)-4-trifluoromethylstyryl-4-bromobenzyisulfone
	81	167-168	63	(E)-2-nitrostyryl-4-cyanobenzyisulfone
	82	192-193	62	(E)-3-nitrostyryl-4-cyanobenzyisulfone
25	83	219-220	66	(E)-4-nitrostyryl-4-cyanobenzyisulfone
	84	182-184	70	(E)-4-fluorostyryl-4-methylbenzyisulfone
	85	191-192	70	(E)-4-bromostyryl-4-methylbenzyisulfone
	86	128-130	51	(E)-2-nitrostyryl-4-methylbenzyisulfone
	87	201-203	56	(E)-3-nitrostyryl-4-methylbenzyisulfone
30	88	194-195	57	(E)-4-nitrostyryl-4-methylbenzyisulfone
	89	148-149	60	(E)-4-fluorostyryl-4-methoxybenzyisulfone
	90	176-177	66	(E)-4-chlorostyryl-4-methoxybenzyisulfone
	91	179-181	60	(E)-4-bromostyryl-4-methoxybenzyisulfone
	92	127-129	57	(E)-2-nitrostyryl-4-methoxybenzyisulfone
	93	153-155	59	(E)-3-nitrostyryl-4-methoxybenzyisulfone
	94	179-181	56	(E)-4-nitrostyryl-4-methoxybenzyisulfone
	95	176-177	66	(E)-4-chlorostyryl-4-nitrobenzyisulfone
	96	199-200	60	(E)-4-fluorostyryl-4-nitrobenzyisulfone

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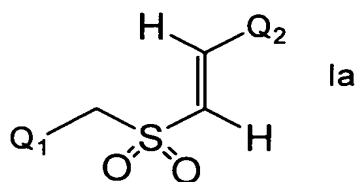
97	133-136	80	(E)-2,3,4,5,6-pentafluorostyryl-4-fluorobenzyisulfone
98	146-148	82	(E)-2,3,4,5,6-pentafluorostyryl-4-chlorobenzyisulfone
99	163-164	85	(E)-2,3,4,5,6-pentafluorostyryl-4-bromobenzyisulfone
100	133-136	78	(E)-4-fluorostyryl-2,3,4,5,6-pentafluorobenzyisulfone
101	154-155	80	(E)-4-chlorostyryl-2,3,4,5,6-pentafluorobenzyisulfone
102	176-177	92	(E)-4-bromostyryl-2,3,4,5,6-pentafluorobenzyisulfone
103	171-173	84	(E)-2,3,4,5,6-pentafluorostyryl-3,4-dichlorobenzyisulfone
104	137-139	84	(E)-2,3,4,5,6-pentafluorostyryl-2,3,4,5,6-pentafluorobenzyisulfone
105	178-181	51	(E)-2,3,4,5,6-pentafluorostyryl-4-iodobenzyisulfone
106	211-212	54	(E)-2-hydroxy-3,5-dinitrostyryl-4-fluorobenzyisulfone
107	207-209	52	(E)-2-hydroxy-3,5-dinitrostyryl-4-bromobenzyisulfone
108	204-205	51	(E)-2-hydroxy-3,5-dinitrostyryl-4-chlorobenzyisulfone
109	212-213	56	(E)-2-hydroxy-3,5-dinitrostyryl-2,4-dichlorobenzyisulfone
110	142-144	52	(E)-2,4,6-trimethoxystyryl-4-methoxybenzyisulfone
111	160-161	52	(E)-3-methyl-2,4-dimethoxystyryl-4-methoxybenzyisulfone
112	138-140	54	(E)-3,4,5-trimethoxystyryl-4-methoxybenzyisulfone
113	ND	ND	(E)-3,4,5-trimethoxystyryl-2-nitro-4,5-dimethoxybenzyisulfone
114	ND	ND	(E)-2,4,6-trimethoxystyryl-2-nitro-4,5-dimethoxybenzyisulfone
115	ND	ND	(E)-3-methyl-2,4-dimethoxystyryl-2-nitro-4,5-dimethoxybenzyisulfone
116	128-129	72	(E)-2,3,4-trifluorostyryl-4-fluorobenzyisulfone
117	141-142	78	(E)-2,3,4-trifluorostyryl-4-chlorobenzyisulfone
118	134-136	58	(E)-2,6-dimethoxy-4-hydroxystyryl-4-methoxybenzyisulfone
119	154-156	56	(E)-2,3,5,6-tetrafluorostyryl-4-methoxybenzyisulfone
120	146-148	66	(E)-2,4,5-trimethoxystyryl-4-methoxybenzyisulfone
121	154-156	52	(E)-2,3,4-trimethoxystyryl-4-methoxybenzyisulfone
122	203-205	56	(E)-3-nitro-4-hydroxy-5-methoxystyryl-4-methoxybenzyisulfone
123	139-141	54	(E)-3,4-dimethoxy-6-nitrostyryl-4-methoxybenzyisulfone
124	160-161	58	(E)-3,4-dimethoxy-5-iodostyryl-4-methoxybenzyisulfone
125	146-148	55	(E)-2,6-dimethoxy-4-fluorostyryl-4-methoxybenzyisulfone
126	ND	ND	(E)-2-hydroxy-4,6-dimethoxystyryl-4-methoxybenzyisulfone

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5	127	97-99	51	(E)-2,4,6-trimethylstyryl-4-methoxybenzylsulfone
	128	181-183	54	(E)-2,4,6-trimethoxystyryl-4-chlorobenzylsulfone
	129	119-121	55	(E)-2,6-dimethoxy-4-fluorostyryl-4-chlorobenzylsulfone
	130	ND	ND	(E)-2-hydroxy-4,6-dimethoxystyryl-4-chlorobenzylsulfone
	131	178-181	54	(E)-2,4,6-trimethoxystyryl-4-bromobenzylsulfone
10	132	116-118	58	(E)-2,6-dimethoxy-4-fluorostyryl-4-bromobenzylsulfone
	133	94-96	52	(E)-2,4,6-trimethoxystyryl-2,3,4-trimethoxybenzylsulfone
	134	110-112	54	(E)-2,6-dimethoxystyryl-2,3,4-trimethoxybenzylsulfone
	135	151-153	54	(E)-2,4,6-trimethoxystyryl-3,4,5-trimethoxybenzylsulfone
	136	146-149	53	(E)-2,6-dimethoxystyryl-3,4,5-trimethoxybenzylsulfone
	137	96-99	68	(E)-4-fluorostyryl-2,3,4-trimethoxybenzylsulfone

ND = Not determined.

Examples of further (E)- α,β unsaturated aryl sulfone compounds according to formula 1a, below, are provided in Table 4. In each compound, one of Q₁ or Q₂ is other than phenyl or substituted phenyl. Each compound was prepared by reacting the appropriate benzylsulfonyl acetic acid or (aryl)methyl sulfonyl acetic acid with the appropriate benzaldehyde or arylaldehyde according to Procedure 1, Part B. 3-Thiophene-1,1-dioxoethenyl compounds were prepared from the corresponding 3-thiopheneethenyl compound by refluxing a solution of the 3-thiopheneethenyl compound in glacial acetic acid (10 ml) and 30% hydrogen peroxide (1 ml) for 1 hour, followed by pouring the cooled contents onto crushed ice (100 g). The solid material separated was filtered and recrystallized from 2-propanol.



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Syn. Ex.	M.P. (°C)	% Yield	Q ₁	Q ₂
138	110-111	54	4-fluorophenyl	2-pyridyl
139	155-156	60	4-fluorophenyl	3-pyridyl
140	ND	52	4-fluorophenyl	4-pyridyl
141	117-119	53	4-chlorophenyl	2-pyridyl
142	167-169	51	4-chlorophenyl	3-pyridyl
143	107-109	53	4-chlorophenyl	4-pyridyl
144	143-145	52	4-bromophenyl	2-pyridyl
145	161-162	59	4-bromophenyl	3-pyridyl
146	158-160	54	4-bromophenyl	4-pyridyl
147	146-148	53	4-fluorophenyl	2-thienyl
149	158-159	56	4-chlorophenyl	2-thienyl
149	169-170	54	4-bromophenyl	2-thienyl
150	155-157	54	4-fluorophenyl	4-bromo-2-thienyl
151	150-151	53	4-chlorophenyl	4-bromo-2-thienyl
152	154-155	54	4-bromophenyl	4-bromo-2-thienyl
153	161-162	55	4-fluorophenyl	5-bromo-2-thienyl
154	190-192	50	4-chlorophenyl	5-bromo-2-thienyl
155	199-200	52	4-bromophenyl	5-bromo-2-thienyl
156	126-128	52	4-fluorophenyl	2-thienyl-1,1-dioxide
157	108-110	55	4-chlorophenyl	2-thienyl-1,1-dioxide
158	145-147	56	4-bromophenyl	2-thienyl-1,1-dioxide
159	159-161	53	4-fluorophenyl	3-thienyl
160	169-170	59	4-chlorophenyl	3-thienyl
161	175-177	70	4-bromophenyl	3-thienyl
162	177-179	52	4-iodophenyl	3-thienyl

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5	163	135-136	55	4-methylphenyl	3-thienyl
	164	130-131	55	4-methoxyphenyl	3-thienyl
	165	201-202	52	4-trifluoro-methylphenyl	3-thienyl
	166	125 -126	53	2,4-dichlorophenyl	3-thienyl
	167	152 -153	51	3,4-dichlorophenyl	3-thienyl
10	168	168-170	54	4-cyanophenyl	3-thienyl
	169	203-205	54	4-nitrophenyl	3-thienyl
	170	95-99	52	4-fluorophenyl	3-thienyl-1,1-dioxide
	171	115-120	51	4-chlorophenyl	3-thienyl-1,1-dioxide
	172	152-155	50	4-bromophenyl	3-thienyl-1,1-dioxide
15	173	92-95	54	4-methoxyphenyl	3-thienyl-1,1-dioxide
	174	135-139	52	2,4-dichlorophenyl	3-thienyl-1,1-dioxide
	175	103-105	53	4-fluorophenyl	2-furyl
	176	106-108	52	4-chlorophenyl	2-furyl
	177	125-127	52	4-bromophenyl	2-furyl
20	178	114-117	51	4-fluorophenyl	3-furyl
	179	154-156	50	4-chlorophenyl	3-furyl
	180	156-158	51	4-bromophenyl	3-furyl
	181	166-170	52	4-iodophenyl	3-furyl
	182	123-126	53	4-methylphenyl	3-furyl
25	183	117-119	51	4-methoxyphenyl	3-furyl
	184	167-169	51	4-trifluoro-methylphenyl	3-furyl
	185	104-106	53	2,4-dichlorophenyl	3-furyl
	186	131-133	52	3,4-dichlorophenyl	3-furyl
	187	175-178	53	4-cyanophenyl	3-furyl
30	188	210-213	52	4-nitrophenyl	3-furyl
	189	133-137	51	4-chlorophenyl	2-thiazolyl
	190	ND	ND	4-chlorophenyl	2-pyrrolyl
	191	ND	ND	4-bromophenyl	2-pyrrolyl
	192	228-230	56	4-chlorophenyl	2-nitro-4-thienyl
	193	177-179	67	4-iodophenyl	2-nitro-4-thienyl
	194	228-230	64	2,4-dichlorophenyl	2-nitro-4-thienyl
	195	170-172	56	4-methoxyphenyl	2-nitro-4-thienyl
	196	148-150	55	4-fluorophenyl	1-naphthyl

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5	197	185-186	58	4-fluorophenyl	2-naphthyl
	198	142-143	63	4-chlorophenyl	1-naphthyl
	199	191-193	52	4-chlorophenyl	2-naphthyl
	200	147-149	52	4-bromophenyl	1-naphthyl
	201	193-194	54	4-bromophenyl	2-naphthyl
10	202	142-144	52	1-naphthyl	4-fluorophenyl
	203	195-197	53	1-naphthyl	4-chlorophenyl
	204	207-209	55	1-naphthyl	4-bromophenyl
	205	188-192	62	1-naphthyl	2-nitrophenyl
	206	192-194	59	1-naphthyl	3-nitrophenyl
	207	252-254	61	1-naphthyl	4-nitrophenyl
	208	93-95	56	4-fluorophenyl	9-anthryl
	209	122-124	53	4-chlorophenyl	9-anthryl
	210	172-175	51	4-bromophenyl	9-anthryl

15 Synthesis Examples 211-213 exemplify the preparation of (E)(Z)-bis(styryl) sulfones. Synthesis Examples 214-219 exemplify the preparation of 2-(phenylsulfonyl)-1-phenyl-3-phenyl-2-propen-1-ones.

Synthesis Example 211

(Z)-styryl-(E)-4-fluorostyryl sulfone

20 A solution of (Z)-styryl sulfonylacetic acid (0.01 mol) and 4-fluorobenzaldehyde (0.01 mol) was subjected to Procedure 3. The title compound was obtained in 68% yield.

Synthesis Example 212

(Z)-styryl-(E)-4-bromostyryl sulfone

25 A solution of (Z)-styryl sulfonylacetic acid (0.01 mol) and 4-bromobenzaldehyde (0.01 mol) was subjected to Procedure 3. The title compound was obtained in 70% yield.

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(Z)-styryl-(E)-4-chlorostyryl sulfone

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2-[(4-fluorophenyl)sulfonyl]-1-phenyl-3-(4-fluorophenyl)-2-propen-1-one

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2-[(2-chlorophenyl)-sulfonyl]-1-phenyl-3-(4-fluorophenyl)-2-propen-1-one

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2-[(2-chlorophenyl)sulfonyl]-1-phenyl-3-(4-bromophenyl)-2-propen-1-one

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2-[(4-chlorophenyl)sulfonyl]-1-phenyl-3-(4-bromophenyl)-2-propen-1-one

A solution of phenacyl-4-chlorophenyl sulfone (0.01 mol) and 4-bromobenzaldehyde (0.01 mol) was subjected to Method 1 of Procedure 4. The title compound was obtained in 60% yield.

2-[(2-nitrophenyl)sulfonyl]-1-phenyl-3-(4-bromophenyl)-2-propen-1-one

A solution of phenacyl-2-nitrophenyl sulfone (0.01 mol) and 4-bromobenzaldehyde (0.01 mol) was subjected to Method 1 of Procedure 4. The title compound was obtained in 56% yield.

2-(phenylsulfonyl)-1-phenyl-3-(4-fluorophenyl)-2-propen-1-one

A solution of phenacylphenyl sulfone (0.01 mol) and 4-fluorobenzaldehyde (0.01 mol) was subjected to Method 1 of Procedure 4. The title compound, melting point 142-143°C, was obtained in 62% yield.

Infrared and nuclear magnetic resonance spectroscopy analyses of the compounds of Synthesis Examples 211 through 218 are set forth in Table 5:

Table 5: IR and NMR Spectroscopy

211	----	1300,1120	6.55(1H,d, $J_{H,H}=10.8$),6.70(1H, d, $J_{H,H}=14.8$), 7.20-7.92 (m,9H aromatic,2H vinyl)
212	----	1318,1128	6.68(1H,d, $J_{H,H}=11.0$),6.86(1H, d, $J_{H,H}=15.0$), 7.15-7.90 (m,9H aromatic,2H vinyl)
213	----	1330,1100	6.65(1H,d, $J_{H,H}=11.2$),6.81(1H, d, $J_{H,H}=15.4$), 7.00-7.85 (m,9H aromatic,2H vinyl)
214	1620	1320,1145	8.04(1H, s, -C=CH) 7.35-7.95(m,13H)
215	1625	1320,1148	8.48(1H, s, -C=CH) 7.40-8.25(m,13H)
216	1618	1315,1140	8.05(1H, s, -C=CH) 7.28-8.00(m,13H)
217	1620	1318,1142	8.47(1H, s, -C=CH) 7.30-8.15(m,13H)
218	1618	1315,1140	8.57(1H, s, -C=CH) 7.40-8.20(m,13H)

Example 1

**Plating Efficiency of Normal vs. Cancer Cells in the
Presence of (E)-4-Fluorostyryl-4-Chlorobenzylsulfone**

HFL-1 cells (normal, human diploid lung fibroblasts) purchased from ATCC were plated after first passage at low density (2.0×10^5 cells) per well (6 well dishes) in one ml of growth medium (DMEM completed with 10% fetal bovine serum and pen/strep). Twenty-four hours later, (E)-4-fluorostyryl-4-chlorobenzylsulfone was added to each well at the following final concentrations; 0 μ M, 2.5. μ M, 5.0 μ M, 25 μ M, 50 μ M, and 75 μ M. After a 24 hour incubation period, the wells were washed 3x with 5 ml normal growth medium and each well was trypsinized and cell counts were determined. To determine colony-forming ability, the cells from each treatment were then serial diluted and replated into 100mm dishes such that each group was split into 3 replating groups consisting of 10, 100, 200 cells per plate. The groups were plated in triplicate. The cells were incubated for 20 days under normal growth conditions and colonies were counted after staining with modified Wright stain (Sigma). The number of colonies from each plate in triplicate were determined and the average for

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each group was plotted. The results are set forth in Fig. 1. The concentration of the drug causing 50% inhibition in plating efficiency was calculated and found to be 70 μ M.

Example 2

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Effect of Long Term Exposure of Normal Human Fibroblasts to (E)-4-Fluorostyryl-4-Chlorobenzylsulfone

HFL-1 cells were plated at a cell density of 1.0×10^5 per well 24 hours prior to drug addition. Cells were exposed to either 2.5 or 5.0 μ M (E)-4-fluorostyryl-4-chlorobenzylsulfone for 48 or 72 hours. Cells were counted 96 hours after the incubation period. The results are shown in Fig. 2. The cells exhibited transiently reduced replication rates.

Example 3

(E)-4-Fluorostyryl-4-Chlorobenzylsulfone Protection of Normal Human Fibroblasts from Paclitaxel Cytotoxicity

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HFL-1 cells were plated at a cell density of 1.0×10^5 per well 24 hours prior to drug addition. Cells were pretreated with (E)-4-fluorostyryl-4-chlorobenzylsulfone (2.0 μ M) for 8 hours and then exposed to paclitaxel (250 μ M). Other cells were treated with paclitaxel alone, or both agents simultaneously. Cells were enumerated by Trypan blue exclusion using a hemacytometer 96 hours after exposure to paclitaxel. The results are shown in Fig. 3. The ordinate in Fig. 3 represents the number of viable cells following treatment with (E)-4-fluorostyryl-4-chlorobenzylsulfone and paclitaxel, divided by the number of viable cells remaining after treatment with paclitaxel alone. Pretreatment with (E)-4-fluorostyryl-4-chlorobenzylsulfone conferred protection from the toxic effects of paclitaxel.

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Example 4

(E)-4-Fluorostyryl-4-Chlorobenzylsulfone Protection of Normal Human Fibroblasts from Anticancer Agent Cytotoxicity

HFL-1 cells were plated at a cell density of 1.0×10^5 in 1 ml of
5 medium. Twenty-four hours following plating, $2.0 \mu\text{M}$ of (E)-4-fluorostyryl-4-
chlorobenzylsulfone was added to the medium. Following a 24 hour
preincubation with the styryl sulfone, the various cytotoxic agents listed in
Table 6 were added to the cells, at the concentrations given in Table 6. the
number of viable cells was determined by Trypan blue exclusion using a
10 hemacytometer 96 hours after exposure to cytotoxic agent. The results
appear in Table 6. The "Protection Ratio" is the number of viable cells
following treatment with (E)-4-fluorostyryl-4-chlorobenzylsulfone and
cytotoxic agent, divided by the number of viable cells remaining after
treatment with cytotoxic agent alone. A protection ratio of 2 or more is
15 considered highly significant, while is protection ratio of 1.5-2 is considered
less significant. As shown in Table 6, normal cells were protected by the
styryl sulfone from the cytotoxic effect of mitotic phase cell cycle inhibitors
and topoisomerase inhibitors, but not from the cytotoxic effect of drugs of
other classes.

Table 6: Protective Effect of (E)-4-Fluorostyryl-4-Chlorobenzylsulfone on HFL-1 Cells Treated with Cytotoxic Drugs

Cytotoxic Drug		Drug Class	Protection Ratio
name	conc. μM		
paclitaxel	0.25	antimitotic	2.5
vincristine	0.25	antimitotic	3.0
camptothecin	0.5	topoisomerase I inhibitor	2.1
etoposide	3.0	topoisomerase II inhibitor	3.5
mitoxantrone	0.3	topoisomerase II inhibitor	2.0
doxorubicin	0.4	topoisomerase II inhibitor	1.5
5-fluorouracil	20	DNA antimetabolite	1.3
cisplatin	5.0	alkylating agent	1.3

Example 5

(E)-4-Fluorostyryl-4-Chlorobenzylsulfone Protection of Normal Human Fibroblasts from Vincristine Cytotoxicity

HFL-1 cells were treated with 0-250 mM vincristine and, optionally, 2.0 μM (E)-4-fluorostyryl-4-chlorobenzylsulfone either 24 hours before or after vincristine treatment, or simultaneously with vincristine treatment. Cell viability was assessed 96 hours after the addition of vincristine. The results are shown in Fig. 4: "V", vincristine alone; "A - V", styryl sulfone followed by vincristine 24 hours later; "A + V", simultaneous styryl sulfone and vincristine treatment; "V - A", vincristine followed by styryl sulfone 24 hours later. Pretreatment with (E)-4-fluorostyryl-4-chlorobenzylsulfone conferred protection from the toxic effects of vincristine.

Example 6

(E)-4-Fluorostyryl-4-Chlorobenzylsulfone Protection of Mice from Paclitaxel Toxicity

ICR female mice age 10-12 weeks (Taconic) were divided into the following treatment groups and received intraperitoneal injections of 50 mg/Kg (E)-4-fluorostyryl-4-chlorobenzylsulfone dissolved in DMSO and/or 150 mg/kg paclitaxel (Taxol, Sigma Chemical Co.) dissolved in DMSO. The styryl sulfone was given 24 hours before paclitaxel, 4 hours before paclitaxel, or simultaneously with paclitaxel. Control animals received paclitaxel alone or styryl sulfone alone. Mortality was assessed 48 and 144 hours after paclitaxel injection. The results are shown in Fig. 5 (48 hours post paclitaxel administration) and Fig. 6 (144 hours post paclitaxel administration). Paclitaxel toxicity in mice is abrogated by pre-treatment with (E)-4-fluorostyryl-4-chlorobenzylsulfone.

Examples 7-12

Antitumor and Cytoprotection Assay of Styryl Sulfones

A. Antitumor Assay

The styryl benzylsulfones listed in Table 7, below, were tested for antitumor activity as follows. A panel of the following human carcinoma cell lines was plated at a cell density of 1.0×10^5 cells per well in six culture plates: prostate tumor cell line DU-145; breast tumor cell line MCF-7; non-small cell lung carcinoma cell line H157; and colorectal carcinoma cell line DLD-1. The compounds were added to the cultures at a final concentration of 2.5 μ M, and 96 hours later the total number of viable cells was determined by counting the number of viable cells, as determined by Trypan blue exclusion, using a hemacytometer. The activity of each compound was determined by comparing the viable cell number of treated to untreated controls. The results appear in Table 7.

B. Cytoprotection Assay

The cytoprotective activity of the same Istyryl benzylsulfones was determined as follows. Normal human HFL-1 cells were plated at a cell density of 1.0×10^5 cells per well in six culture plates. Styryl benzylsulfone was added 24 hours later at a final concentration of either 2.0 or 10 μ M. The time of styryl sulfone addition was designated as time zero. Paclitaxel (250 nM) was added at either time zero, or 24 hours after time zero. The total number of viable cells was determined, as described above, after 96 hours of paclitaxel treatment. A compound was deemed to be active if the number of viable cells following the combination treatment was higher than the number of cells after treatment with paclitaxel alone. The data are set forth in Table 7.

Table 7: Antitumor and Cytoprotective Effect of Styryl Sulfones

Ex.	Compound	Antitumor	Cytoprotection
7	(E)-4-fluorostyryl-4-chlorobenzyl sulfone	+	+
8	(E)-4-chlorostyryl-4-chlorobenzyl sulfone	+	+
9	(E)-2-chloro-4-fluorostyryl-4-chlorobenzyl sulfone	+	+
10	(E)-4-carboxystyryl-4-chlorobenzyl sulfone	-	+
11	(E)-4-fluorostyryl-2,4-dichlorobenzyl sulfone	+	+
12	2-(phenylsulfonyl)-1-phenyl-3-(4-fluorophenyl)-2-propen-1-one	-	+

All references discussed herein are incorporated by reference. One skilled in the art will readily appreciate that the present invention is well adapted to carry out the objects and obtain the ends and advantages mentioned, as well as those inherent therein. The present invention may be embodied in other specific forms without departing from the spirit or essential attributes thereof and, accordingly, reference should be made to the appended claims, rather than to the foregoing specification, as indicating the scope of the invention.